UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195

Department of Computer Science and Engineering
Box 352350
206 685-1227 / FAX 206 543-2969
salesin@cs.washington.edu

31 July 1995

Dr. Ralph Wachter
Program Manager/Officer ONR:311
Office of Naval Research
Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660

Dear Dr. Wachter:

Here is a brief summary of some of the most significant advances during the past quarter, on ONR Young Investigator Award number N00014-95-1-0728:

Fast multiresolution image querying,[1] with Charles Jacobs (a UW undergraduate) and Adam Finkelstein (a UW Ph.D. student). In this project, we have developed a method for searching in an image database using a query image that is similar to the intended target. The query image may be a hand-drawn sketch or a (potentially low-quality) scan of the image to be retrieved. Our searching algorithm makes use of multiresolution wavelet decompositions of the query and database images. The coefficients of these decompositions are distilled into small "signatures" for each image. We introduce an "image querying metric" that operates on these signatures. This metric essentially compares how many significant wavelet coefficients the query has in common with potential targets. The metric includes parameters that can be tuned, using a statistical analysis, to accommodate the kinds of image distortions found in different types of image queries. The resulting algorithm is simple, requires very little storage overhead for the database of signatures, and is fast enough to be performed on a database of 20,000 images at interactive rates (on standard desktop machines) as a query is sketched. Our experiments with hundreds of queries in databases of 1000 and 20,000 images show dramatic improvement, in both speed and success rate, over using a conventional L^1, L^2, or color histogram norm. We completed the final version of this paper during the last quarter and will be presenting the results at SIGGRAPH 95 next week.

[1] Charles Jacobs, Adam Finkelstein, and David H. Salesin. Fast multiresolution image querying. To appear at SIGGRAPH 95, August 1995. Available as Department of Computer Science and Engineering Technical Report TR 95-01-06B, University of Washington, May 1995.

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
SEATTLE REGIONAL OFFICE
1107 NE 45TH STREET, SUITE 350
SEATTLE WA 98105-4631

IN REPLY REFER TO:

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ONR 247
11 Jul 97

From: Director, Office of Naval Research, Seattle Regional Office, 1107 NE 45th St., Suite 350, Seattle, WA 98105
To: Defense Technical Center, Attn: P. Mawby, 8725 John J. Kingman Rd., Suite 0944, Ft. Belvoir, VA 22060-6218

Subj: RETURNED GRANTEE/CONTRACTOR TECHNICAL REPORTS

1. This confirms our conversations of 27 Feb 97 and 11 Jul 97. Enclosed are a number of technical reports which were returned to our agency for lack of clear distribution availability statement. This confirms that all reports are unclassified and are "APPROVED FOR PUBLIC RELEASE" with no restrictions.

2. Please contact me if you require additional information. My e-mail is *silverr@onr.navy.mil* and my phone is (206) 625-3196.

ROBERT J. SILVERMAN

Clustering for glossy global illumination,[2] to *ACM Transactions on Graphics* with Per Christensen (a UW Ph.D. student), Dani Lischinski (a UW post-doc), and Eric Stollnitz (a UW Ph.D. student in Applied Math). In June, we submitted a paper, which presents a new clustering algorithm for global illumination in complex environments. The new algorithm extends previous work on clustering for radiosity to allow for non-diffuse (glossy) reflectors. We treat each cluster as a point source with an angular distribution of radiant intensity, and we derive an error bound for transfers between these clusters. The algorithm groups input surfaces into a hierarchy of clusters, and then permits clusters to interact only if the error bound is below an acceptable tolerance. We show that the algorithm is asymptotically more efficient than previous clustering algorithms even when restricted to ideally diffuse environments. Finally, we demonstrate a working implementation of the algorithm on a complex architectural environment. This work is the last piece of a complete hierarchical glossy global illumination algorithm, which is described in full in Per Christensen's recently-completed Ph.D. dissertation.[3]

Wavelets in computer graphics, with Eric Stollnitz and Tony DeRose (a UW Professor). Wavelets are an exciting new mathematical tool, with roots in approximation theory, signal processing, and physics, that can be used for hierarchically decomposing functions. Wavelets have found a wide variety of applications in recent years, including signal analysis, image processing, and numerical analysis. Even more recently, wavelets are finding numerous applications in computer graphics, including image[4] and curve editing[5] and fast methods for solving simulation problems in global illumination.[6] To make the rather complex wavelets theory more accessible to the computer graphics community, we have written a primer[7] that recently appeared in two parts in *IEEE Computer Graphics and Applications*. We are currently writing a 300-page research monograph on the subject, which we expect

[2]Per H. Christensen, Dani Lischinski, Eric J. Stollnitz, and David H. Salesin. Clustering for glossy global illumination. Submitted to *ACM Transactions on Graphics*. Available as Department of Computer Science and Engineering Technical Report TR 95-01-07B, University of Washington, June 1995.

[3]Per H. Christensen. *Hierarchical Techniques for Glossy Global Illumination.* PhD thesis, University of Washington, July 1995.

[4]Deborah Berman, Jason Bartell, and David H. Salesin. Multiresolution painting and compositing. Proceedings of SIGGRAPH 94, in *Computer Graphics* Proceedings, Annual Conference Series, 85–90, July 1994.

[5]Adam Finkelstein and David H. Salesin. Multiresolution curves. Proceedings of SIGGRAPH 94, in *Computer Graphics* Proceedings, Annual Conference Series, 261–268, July 1994.

[6]Per Christensen, Eric Stollnitz, Tony DeRose, and David Salesin. Global illumination of glossy environments using wavelets and importance. Submitted to *ACM Transactions on Graphics*. Available as Department of Computer Science and Engineering Technical Report TR 94-10-01, University of Washington, October 1994.

[7]Eric Stollnitz, Tony DeRose, and David Salesin. Wavelets for computer graphics: A primer. Published in two parts in *IEEE Computer Graphics and Applications* 15(3): 76–84 and 15(4): 75–85, May and July 1995.

to publish in the next year through Morgan-Kaufmann.[8]

Rendering of complex environments using a spatial hierarchy,[9] with Brad Chamberlain (a UW Ph.D. student), Tony DeRose, Dani Lischinski, and John Snyder (from Microsoft Research). We have been investigating methods for accelerating the rendering of complex static scenes. One approach we have developed, is to place a spatial hierarchical decomposition over the scene and to construct a simplified representation of each cell in the hierarchy that approximates the general appearance of its contents. The scene is then rendered, using a traversal of the hierarchy in which a cell's approximation is drawn if the approximation is sufficiently accurate. One advantage of the approach is in its generality: it is applicable to unstructured scenes consisting of arbitrary geometric primitives and does not rely on the presence of any specific occlusive qualities in the scene to achieve its speed. In the technical report, we present performance results from applying the method to several different scenes, and we discuss artifacts caused by the approximation. We also address limitations in the current implementation and present our plans to circumvent these problems.

I would be more than happy to furnish any or all of these papers, or discuss this work in more detail, upon your request.

Sincerely,

David Salesin
Assistant Professor

[8]Eric Stollnitz, Tony DeRose, and David Salesin. *Wavelets for Computer Graphics*. Morgan-Kaufmann Publishers, Inc. Research monograph, in preparation.

[9]Brad Chamberlain, Tony DeRose, Dani Lischinski, David Salesin, and John Snyder. Rendering of complex environments using a spatial hierarchy, Department of Computer Science and Engineering Technical Report TR 95-05-02, University of Washington, May 1995.